Attorney Docket 36856.283

METHOD OF FIRING MAGNETIC CORE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of firing magnetic cores, and more particularly, to a method of firing flattened-ring magnetic cores included in noise-suppressing components and other such apparatuses, as well as, a method of firing thin magnetic cores included in noise filters, inductors of transformers, and other such apparatuses.

2. Description of the Related Art

A flattened-ring magnetic core 21 shown in FIG. 5 is known for use as a core in a noise-suppressing component. A signal line such as a flat cable is inserted into a flattened through-hole 22 of the magnetic core 21, and high-frequency noise propagating through the signal line is eliminated. Typically, a cross section of the magnetic core 21 has a length L of a longer side of 10 mm to 100 mm and a length T of a shorter side of 1 to 10 mm, and the through-hole 22 has a length t of a short side of 0.3 mm to 8 mm. The magnetic core 21 is assembled and fired by providing a plurality of flattened-ring compact bodies, which are made of a ferrite material and are provided with the flattened through-holes 22, at an opening surface thereof in a firing container (not shown in the drawing) so that the axes of the through-holes 22 are vertically oriented, and then firing the compact bodies 21 in this arrangement.

A thin magnetic core 210 shown in FIG. 10 is known for use in a noise filter, an inductor of a transformer, and other such components. The core 210 is assembled and fired by arranging a plurality of thin compact bodies 210 made of a ferrite material vertically at one side thereof in a firing container (not shown in the drawing), and firing the compact bodies in this arrangement.

At this stage, each of the flattened-ring compact bodies 21 or the thin compact bodies 210 is spaced apart so that adjacent flattened-ring compact bodies 21 or adjacent thin compact bodies 210 do not stick together during firing. If the adjacent flattened-ring compact bodies 21 or the adjacent thin compact bodies 210 stick together, a chemical reaction may occur in the compact bodies when connected together or contacting each other, or breaks or cracks may occur when the connected compact bodies 21 or 210 are detached from each other by applying mechanical force.

With respect to the conventional method of firing magnetic cores, it is relatively easy to arrange the compact bodies 21 or 210 in a perpendicular orientation in a firing container in which they are placed with sufficient space when the compact bodies 21 or 210 are large, and in particular, when the compact bodies 210 are thick. In such a case, even if slight vibrations and shocks are applied, the flattened-ring compact bodies 21 or the thin compact bodies 210 are not inclined, and the adjacent flattened-ring compact bodies 21 or the adjacent thin compact bodies 210 do not easily stick together during firing.

However, recently, as magnetic cores become thinner and smaller, it is often necessary to fire small flattened-ring compact bodies 21 or small thin compact bodies 210 while they are vertically oriented and spaced apart from each other. In such a case, it is difficult to vertically position separately each of the small flattened-ring compact bodies 21 or the small thin compact bodies 210. When the compact bodies 21 or 210 are small, slight vibrations easily cause the compact bodies 21 or 210 to be tilted, and the adjacent flattened-ring compact bodies 21 or thin compact bodies 210 are

brought into contact with each other, and thus a chemical reaction may occur therebetween, or adherence, breaks, or cracks which are not visibly detectable may occur, resulting in an increase in the defect rate, or a decline in reliability of the product.

SUMMARY OF THE INVENTION

In order to overcome the problems described above, preferred embodiments of the present invention provide a method of firing magnetic cores in which firing is performed with a high degree of reliability and mass production is enabled.

According to one preferred embodiment of the present invention, a method of firing magnetic cores includes the steps of attaching a powder to the surface of a plurality of flattened-ring compact bodies made of a magnetic material and having flattened through holes, arranging the plurality of flattened-ring compact bodies adjacently so that the axes of the flattened through-holes of the flattened-ring compact bodies are vertically oriented, and firing the flattened-ring compact bodies while the powder is interposed between the adjacent flattened-ring compact bodies. The powder may preferably include an inorganic material or an organic material having particles with a particle size of about 1,000 μm or less.

In another preferred embodiment of the present invention, a method of firing magnetic cores includes the steps of attaching a powder to the surface of a plurality of thin compact bodies made of a magnetic material, vertically arranging the plurality of thin compact bodies adjacently, and firing the thin compact bodies while the powder is interposed between the adjacent thin compact bodies. The powder may preferably include an inorganic material or an organic material having particles with a particle size of about 1,000 μm or less.

The powder attached to the surface of the compact bodies functions as a spacer between the adjacent compact bodies. Therefore, the compact bodies can be arranged

in the container by stacking them together, thus facilitating the setting operation. When the compact bodies are fired, the adjacent compact bodies are not brought into direct contact with each other, and thus inconveniences such as reactions in the contact surface therebetween, adherence, and breaks do not occur.

Other features, elements, advantages, steps and characteristics of the present invention will be described in more detail below with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating a step in a method of firing flattened-ring magnetic cores in accordance with preferred embodiments of the present invention;

FIG. 2 is a diagram illustrating a step in the method of firing flattened-ring magnetic cores in accordance preferred embodiments of with the present invention;

FIG. 3 is a diagram illustrating a step in the method of firing flattened-ring magnetic cores in accordance with preferred embodiments of the present invention;

FIG. 4 is a diagram illustrating a step in the method of firing flattened-ring magnetic cores in accordance with preferred embodiments of the present invention;

FIG. 5 is a diagram illustrating a conventional method of firing flattened-ring magnetic cores;

FIG. 6 is a diagram illustrating a step in a method of firing thin magnetic cores in accordance with preferred embodiments of the present invention;

FIG. 7 is a diagram illustrating a step in the method of firing thin magnetic cores in accordance with preferred embodiments of the present invention;

FIG. 8 is a diagram illustrating a step in the method of firing thin magnetic cores in accordance with preferred embodiments of the present invention;

FIG. 9 is a diagram illustrating a step in the method of firing thin magnetic cores in accordance with preferred embodiments of the present invention; and

FIG. 10 is a diagram illustrating a conventional method of firing thin magnetic cores.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A preferred embodiment of a method of firing magnetic cores in the present invention will be described with reference to FIGs. 1 to 4.

As shown in FIG. 1, a plurality of flattened-ring compact bodies 1 are prepared. The flattened-ring compact bodies 1 are formed such that a powdered magnetic material such as a ferrite which is mixed with a binder, or other suitable material, is molded into flattened-rings having flattened through-holes 2. Each of the flattened-ring compact bodies 1 is arranged so that the axis of the through-hole 2 is arranged horizontally. Next, as shown by an arrow A in FIG. 1, a powder is sprinkled uniformly over the flattened-ring compact bodies 1. The powder preferably includes particles having a particle size of about 1,000 μm or less, and is made of an organic material or an inorganic material. An organic material may include a material which is vaporized during firing. Examples of the organic material include polyvinyl alcohol-based synthetic resins, cellulosic synthetic resins, and natural organic materials such as wheat flour and potato starch. The inorganic material may include a material which does not react with the flattened-ring compact bodies 1 during firing. Examples of the inorganic material include alumina and zirconia.

If the particle size of the powder exceeds about 1,000 μm, the attachment of the powder to the flattened-ring compact bodies 1 is weakened, and when the flattened-ring compact bodies 1 are vertically placed in a subsequent step, the powder easily falls from the surfaces of the flattened-ring compact bodies 1, thus decreasing the setting

efficiency of the flattened-ring compact bodies 1. However, by mixing a powder having a particle size of about 1,000 μm or less with the powder having the particle size of more than about 1,000 μm, the decrease of the setting efficiency is prevented.

On the other hand, although a powder having a particle size of about 20 μm or less has a slightly inferior function as a spacer for preventing adherence of the flattened-ring compact bodies 1, it is possible to easily detach the flattened-ring compacts 1, which are stuck together, by lightly applying mechanical force.

Next, as shown in FIG. 2, a predetermined number of flattened-ring compact bodies 1 to which the powder is attached are stacked together while aligning the axial direction of the individual compact bodies 1 horizontally. The powder is interposed between the adjacent flattened-ring compact bodies 1 which are stacked together. Then, as shown in FIG. 3, the flattened-ring compact bodies 1 are arranged in a firing container (not shown in the drawing), in which an inorganic powder (such as a high-purity alumina powder or zirconia powder) that does not chemically react with the flattened-ring compact bodies 1 is spread all over, so that the axes of the flattened-ring compacts are vertically oriented while maintaining the stacked state. Additionally, it may not be necessary to spread the inorganic powder in the firing container depending on the shape of the flattened-ring compact bodies 1 or the material of the firing container.

Next, as shown in FIG. 4, bars 3 made of high-purity alumina, zirconia, or the like are attached to the sides of the stacked flattened-ring compact bodies 1 so as to prevent the vertically placed flattened-ring compact bodies 1 from falling or tilting. The flattened-ring compact bodies 1 which have been arranged as described above are fired in a firing furnace. Accordingly magnetic cores are obtained by firing the flattened-ring compact bodies 1.

The powder attached to the surface of the flattened-ring compact bodies 1 functions as a spacer between the adjacent flattened-ring compact bodies 1. Therefore,

the flattened-ring compact bodies 1 can be arranged by stacking together, thus facilitating the arranging operation. When the flattened-ring compact bodies 1 are fired, the adjacent flattened-ring compact bodies 1 are not brought into direct contact with each other, and thus inconveniences such as reactions therebetween, adherence, and breaks do not occur.

Additionally, the present invention is not limited to preferred embodiments described above. For example, although the powder is sprinkled over the flattened-ring compact bodies in preferred embodiments described above, the powder may be fixedly applied to the flattened-ring compact bodies by spraying or other such processes.

Another preferred embodiment of a method of firing magnetic cores in the present invention will be described with reference to FIGs. 6 to 9.

As shown in FIG. 6, a plurality of thin compact bodies 10 are prepared. The thin compact bodies 10 are formed such that a powdered magnetic material such as a ferrite which is mixed with a binder, or other suitable material is molded into a substantially E-shaped configuration. The thin compact bodies 10 have a length L1 of a longer side, a length L2 of a shorter side and a thickness t of the thin green compact 10. The thickness t of the thin green compact 10 is about one third or less of the length L2 of the shorter side. Each of the thin compact bodies 10 is arranged horizontally. Next, as shown by an arrow A in FIG. 6, a powder is sprinkled uniformly over the thin compact bodies 10. The same powder as that in first preferred embodiment is preferably used.

As shown in FIG. 7, a predetermined number of thin compact bodies 10 to which the powder is attached are stacked together by aligning the axial direction of the individual compact bodies 10 horizontally. The powder is interposed between the adjacent thin compact bodies 10 which are stacked together. Then as shown in FIG. 8, the thin compact bodies 10 are arranged in a firing container (not shown in the drawing), in which an inorganic powder (such as a high-purity alumina powder or zirconia powder) that does not chemically react with the thin compact bodies 10 is spread all over, so that

the thin compact bodies 10 are vertically oriented while maintaining the stacked state. Additionally, it may not be necessary to spread the inorganic powder in the firing container depending on the shape of the thin compact bodies 10 or the material of the firing container.

Next, as shown in FIG. 9, bars 30 made of high-purity alumina, zirconia, or other suitable material are attached to the sides of the stacked thin compact bodies 10 so as to prevent the vertically placed thin compact bodies 10 from falling. The thin compact bodies 10 which have been set as described above are fired in a firing furnace. Magnetic cores are obtained by firing the thin compact bodies 10. Accordingly the preferred embodiment shown in Fig. 6 is manufactured by the method similar to the preferred embodiment shown in Fig. 1, and similar advantages are achieved.

Additionally, the present invention is not limited to the preferred embodiments described above, and various other structures may be adopted within the scope of the present invention. For example, although the powder is sprinkled over the thin compact bodies in the preferred embodiments described above, the powder may be fixedly applied to the thin compact bodies by spraying or other processes. The magnetic core may be U-shaped, I-shaped, ring-shaped, rectangular-shaped with a central dividing line, square-shaped, or have other suitable shapes instead of being E-shaped.

EXAMPLES 1 to 8

Flattened-ring compact bodies 1 (refer to FIG. 1) with outer dimensions in which the length L of a longer side = 22.8 mm, the length T of a shorter side = 2.8 mm, and the length in the axial direction = 12.0 mm were prepared. The through-holes 2 had a length of a longer side of 18.7 mm and a length t of a shorter side of 0.7 mm. The flattened-ring compact bodies 1 were made of a NiZn ferrite material. Various materials shown in Table 1 below were prepared as powders. After the flattened-ring compact bodies 1 were arranged so that the axes of the through-holes 2 were horizontally oriented, the individual powders shown in Table 1 were sprinkled through a mesh

screen uniformly over the flattened-ring compact bodies 1. The flattened-ring compact bodies 1 were stacked together so that the axes were arranged vertically with the sprinkled powders being interposed.

The flattened-ring compact bodies 1 were arranged in 5 rows, with 32 bodies per row, in a firing container in which zirconia powder was spread all over, and bars 3 made of zirconia were attached. Thirty samples of such firing containers in which flattened-ring compact bodies 1 set as described above were prepared (4,800 pieces of flattened-ring compact bodies in total) for each example, and firing was performed in an electric furnace at 1,000 to 1,200°C. Table 1 shows the evaluation results with respect to the adherence rate and the defect rate of the fired magnetic cores (examples 1 to 8). Additionally, Table 1 also includes the evaluation results of magnetic cores fired in a conventional method (comparative example).

Table 1

	Powder	Average Particle Size (µm)	Particle Size Range (µm)	Adherence Rate (%)	Defect Rate (%)
Example 1	polyvinyl alcohol-based	600	120 to 1,000	0	0
Example 2	polyvinyl alcohol-based	200	60 to 400	0	0
Example 3	cellulosic	40	20 to 60	15	0
Example 4	wheat flour	70	50 to 80	0	0
Example 5	high-purity alumina	800	300 to 1,000	0	0
Example 6	high-purity alumina	200	70 to 360	0	0
Example 7	high-purity alumina	80	40 to 150	0	0
Example 8	high-purity alumina	40	20 to 70	14	0
Comparative Example				57	2.7

As is obvious from Table 1, when firing was performed using the cellulosic powder in example 3 and using the high-purity alumina powder having an average particle size of about 40 μm in example 8, adherence occurred in the magnetic cores at rates of 15% and 14%, respectively. However, in both examples, the magnetic cores were easily detached by lightly applying mechanical forces to the stuck magnetic cores, and satisfactory quality was also obtained, and thus, the defect rate was 0%.

EXAMPLES 9 to 16

Thin compact bodies 10 (refer to FIG. 6) with outer dimensions in which the length L1 of a longer side = 24.0 mm, the length L2 of a shorter side = 12.0 mm, and the thickness t = 2.8 mm were prepared. The thin compact bodies 10 were made of a NiZn ferrite material. Various materials shown in Table 2 below were prepared as powders. After the thin compact bodies 10 were arranged horizontally, the individual powders shown in Table 2 were sprinkled through a mesh screen uniformly over the thin compact bodies 10. The thin compact bodies 10 were stacked together with the sprinkled powders being interposed so as to be oriented vertically.

In accordance with the steps shown in FIGs. 7 to 9, the thin compact bodies 10 were arranged in 5 rows, with 32 pieces bodies row, in a firing container in which zirconia powder was spread all over, and bars 30 made of zirconia were attached. Thirty samples of such firing containers in which thin compact bodies 10 were set as described above were prepared (4,800 pieces of thin compact bodies 10 in total) for each example, and firing was performed in an electric furnace at 1,000 to 1,200°C. Table 2 shows the evaluation results with respect to the adherence rate and the defect rate of the fired magnetic cores (examples 9 to 16). Additionally, Table 2 also includes the evaluation results of magnetic cores fired in a conventional method (comparative example).

Table 2

	Powder	Average Particle Size (μm)	Particle Size Range (μm)	Adherence Rate (%)	Defect Rate (%)
Example 9	polyvinyl alcohol-based	600	120 to 1,000	0	0
Example 10	polyvinyl alcohol-based	200	60 to 400	0	0
Example 11	cellulosic	40	20 to 60	12	0
Example 12	wheat flour	70	50 to 80	0	0
Example 13	high-purity alumina	800	300 to 1,000	0	0
Example 14	high-purity alumina	200	70 to 360	0	0
Example 15	high-purity alumina	80	40 to 150	0	0
Example 16	high-purity alumina	40	20 to 70	13	0
Comparative Example				45	2.2

As is seen in Table 2, when firing was performed using the cellulosic powder in example 11 and using the high-purity alumina powder having an average particle size of about 40 μm in example 16, adherence occurred in the magnetic cores at rates of 12% and 13%, respectively. However, in both examples, magnetic cores were easily detached by lightly applying mechanical shocks to the stuck magnetic cores, and satisfactory quality was also obtained, and thus, the defect rate was 0%.

As described above, in accordance with preferred embodiments of the present invention, the powder attached to the surface of magnetic compact bodies shown in the examples functions as a spacer between the adjacent compact bodies. Therefore, the compact bodies can be arranged by stacking together, thus facilitating the arranging operation. When the compact bodies are fired, the adjacent compact bodies are not brought into direct contact with each other, and thus inconveniences such as reactions therebetween, adherence, and breaks are reliably prevented. Accordingly, it is possible to efficiently fire magnetic cores with a high degree of reliability, and the defect rate is significantly reduced.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit of the invention.